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STUDIES IN FLAME PROPIGATION AND BLOWOUT

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SUMMARY/OVERVIEW:

This report outlines our most recent research work on the topic of upstream flame propagation and blowout in hydrocarbon jet flames. Outlined specifically are the recent elements of the research for the study of fundamental structural characteristics of jet flames and related flame/spray/flow interactions. Specifically, the scope encompasses further optical imaging investigations of flame structure and behavior, and an exploratory study of the effects of co-flow air on extinction and blowout. Analysis of the results of experiments to understand the behavior of gaseous and spray flame counterparts is the main deliverable. The methodology of the research is largely experimental, emphasizing the application of optical diagnostic techniques to instantaneously visualize reaction zones. The main efforts to report since the last update are the following: 1) Studies have been launched that examine the development of combustion in an initially non-reacting methane jet after ignition at a downstream location and 2) The driving mechanisms that cause jet-flame blowout, particularly in the presence of air co-flow, have been investigated. This work attempts to determine the role of fuel velocity and air co-flow in the blowout phenomenon.

TECHNICAL DISCUSSION:

1) Observations on Upstream Flame Propagation in Ignited Hydrocarbon Jets

While laminar lifted jet flames have been extensively investigated both analytically and experimentally, transitional and turbulent regions have received less attention. The goal of this study is to investigate downstream ignition in initially non-reacting turbulent hydrocarbon jets (Lyons and Watson 2001) issuing with air co-flow. The farthest distance from the burner at which the flame will propagate upstream to its stable position upon application of an ignition source, hereafter referred to as the "upper propagation limit", is determined and presented for eleven different cases. The nine prime cases consisted of three jet Reynolds numbers at three co-flow velocities. In addition to the nine prime cases two outlier cases were also examined. It is seen that there is an inverse relationship between the upper propagation limit position and the Reynolds number. There is also an inverse relationship between the upper propagation limit and the co-flow velocity. The effect of co-flow is partially explained by the approach presented by Han and Mungal (2000). The overall goal is to report what these results imply about the stabilization and propagation of turbulent lifted jet flames.

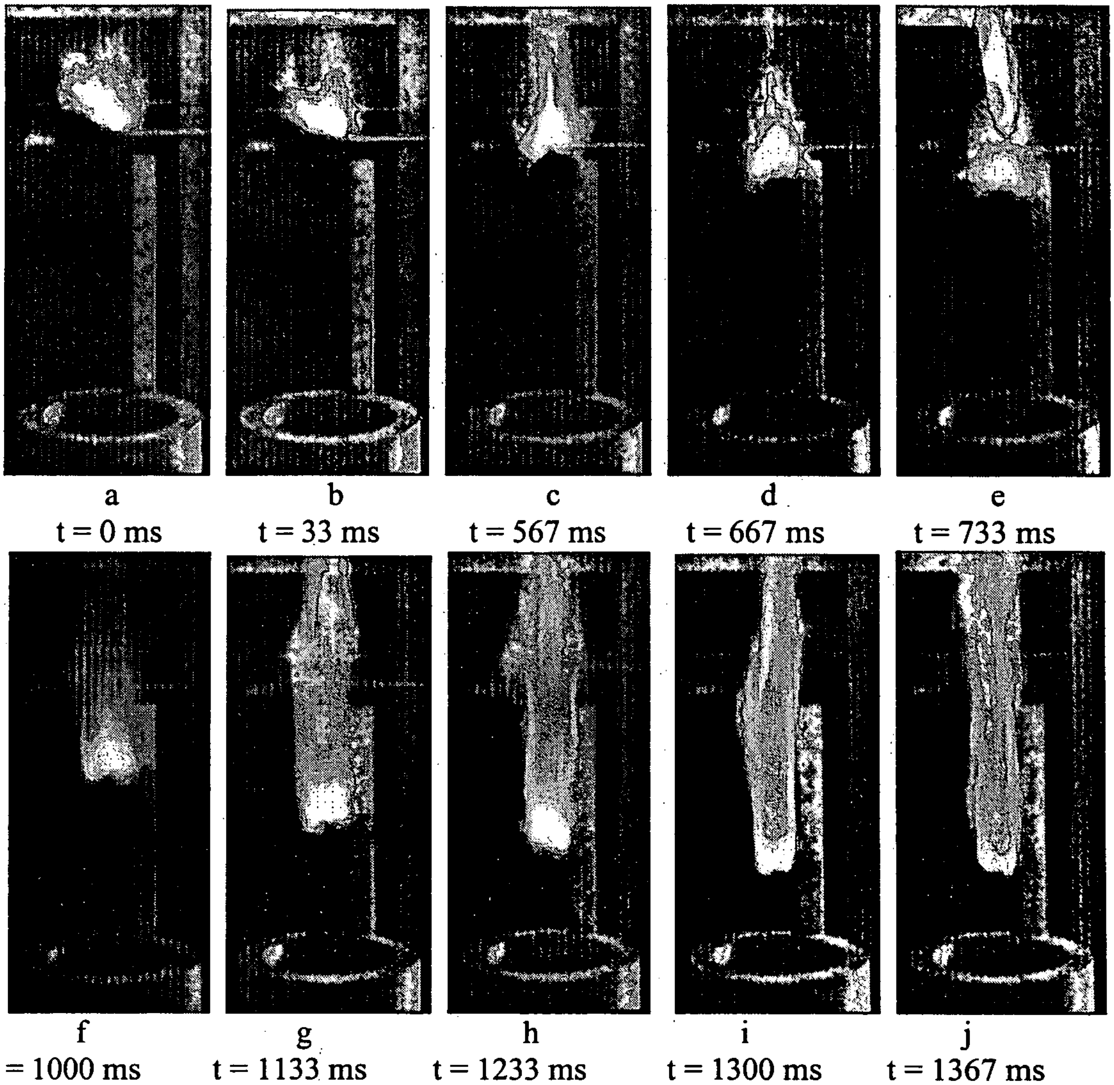

Figure 1: Propagation of methane flame from upper propagation limit (23.7 cm) to stable height (7.62 cm).

Figure 1 is the depiction of a methane flame propagating from its upper propagation limit to its stable height. The fuel velocity for this case was 35.6 m/s and there was no co-flow present. The Reynolds number for this case was 8242. These particular conditions caused the flame to be lifted from the burner. The height at which the flame stabilized at was 7.6 cm downstream from the nozzle. The upper propagation limit for this case was 23.7 cm (this is the axial position <u>above which</u> (father downstream) a locally ignited region with the same ignition source cannot counter-propagate against the incoming flow and the local ignition kernel goes out/blows off – ignition attempted <u>closer</u> to the nozzle than 23.7 cm permits the reaction zone to propagate upstream).

At 0 ms, a, the flame is unable to sustain itself. The ignition source is required to keep the flame burning locally. In c the flame begins to propagate on its own. The total time for the flame to fully propagate from the upper propagation limit to its stable height of 7.62 cm is 800 ms. Many cases have been examined for various jet velocities, co-flow velocities and work to understand the data is ongoing (McCraw et al. 2006).

2) Effects of Co-flow on Turbulent Lifted Flames near Blowout Condition

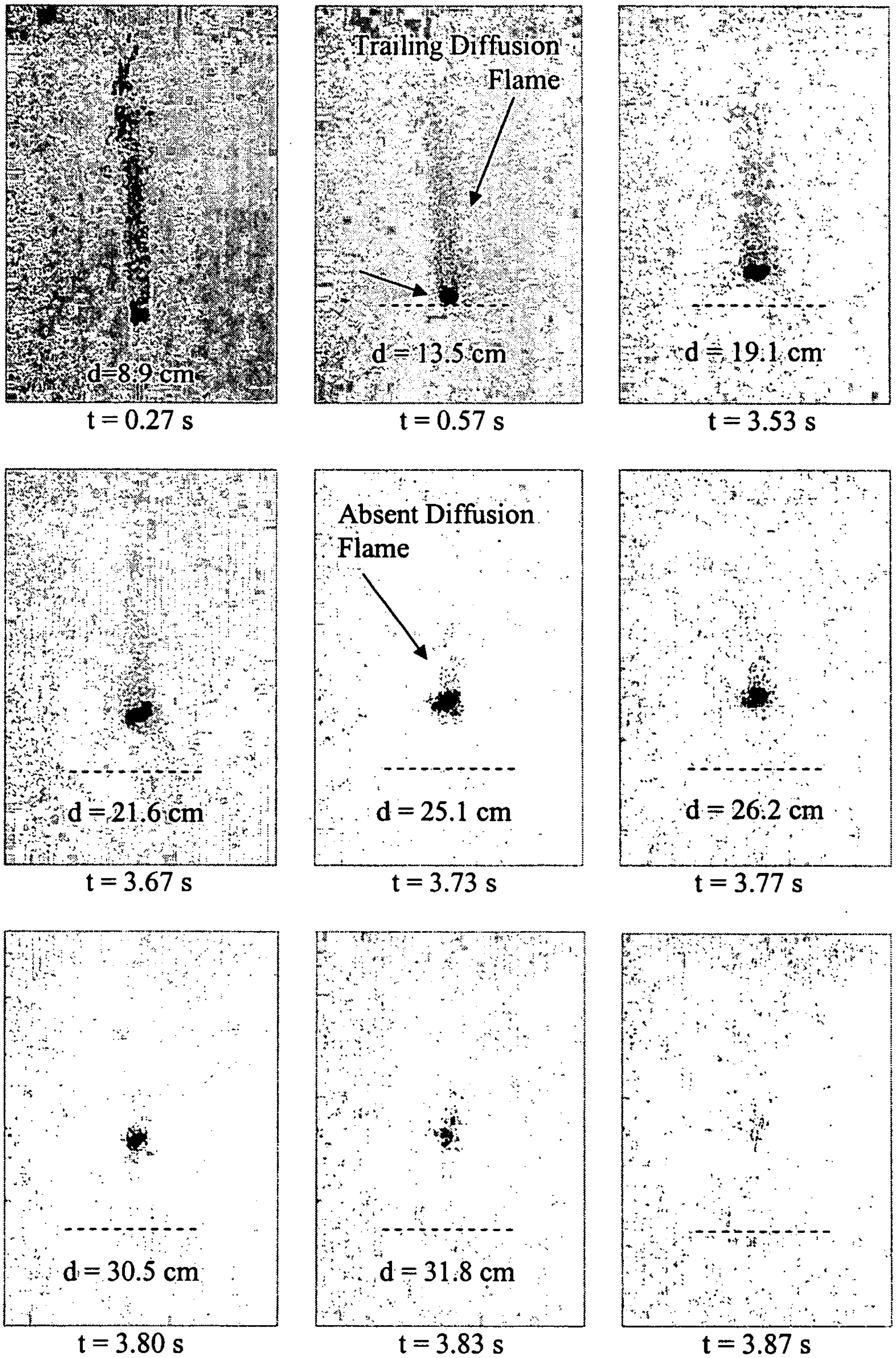

Figure 2. Images after re-ignition at the fuel nozzle at $t = 0$ with d indicating the distance downstream of the flame front from the nozzle. The nozzle is within the image borders but is not visible in these enhanced images. The dotted line indicates the position of the meta-stable flame front.

The driving mechanisms that cause jet-flame blowout, particularly in the presence of air co-flow, are not completely understood. This work attempts to determine the role of fuel velocity and air co-flow in the blowout phenomenon. The results of video imaging of the reaction zone upon removal of the ignition source at blowout conditions are characterized. Data from a series of experiments are collected at various co-flow and jet velocities. Images are used to ascertain the changes in the leading edge of the reaction zone prior to flame extinction. These changes can help develop a physically-based model to describe jet-flame blowout.

Figure 2 contains a sequence of images of the flame re-ignited at the nozzle with 0.55 m/s co-flow and 34.3 m/s fuel. After 0.57 seconds, the flame has reached a meta-stable position of 135 mm. It stays at this lifted height for approximately 3 seconds, at which time the trailing diffusion flame begins to disappear indicating the beginning of the blowout sequence. The diffusion flame is absent 3.73 seconds after re-ignition and blowout occurs 0.14 seconds later with complete loss of the leading edge reaction zone. The duration at the meta-stable lifted position appears random. However, the behavior of the flame beyond this position is independent of co-flow or fuel velocity. Analysis of the blowout conditions are currently underway utilizing the approach of Tieszen et al. (Moore et al. 2006).

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